REMARKS

Claims 1, 9-11, 19 and 20 were pending in the application. In the Office Action mailed December 1, 2010, claims 1, 9-11, 19 and 20 are rejected. In the instant Amendment, claims 1 and 9 have been amended to make the language clearer, and new claims 21-22 have been added. Support for new claims 21-22 is found in the specification at, e.g., Table 1, Example K, and Table 11, Example R, respectively. Upon entry of the instant Amendment, claims 1, 9-11, 19 and 20-22 will be pending in the application.

No new matter has been added by these amendments. Entry of the foregoing amendment and consideration of the following remarks are respectfully requested.

Rejection Under 35 U.S.C. § 103

Claims 1, 9-11, 19 and 20 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Tsutomu JP2001-342543 (JP'543) in view of Yasuhara et al. US 6,364,968 (US'968) and in view of U.S. Patent No. 5,470,529 ("US'529") to Nomura et al.

Claims 1 and 16 are directed to steel sheets having a structure of primarily bainite, claims 9-11 are directed to steel sheets with having a ferrite + bainite structure, both of which achieve superior strength, expandability and ductility.

The present inventors has discovered that hole-expandability is remarkably improved by the formation of Mg-sulfides, which conventionally has not been recognized. Controlling the amounts of Mg, O, S, and Mn according to equations (1) to (3) allows the precipitation of Mg-sulfides while impeding the precipitation of Mn-sulfides resulting in the combined precipitation of MgO, MgS and (Nb,Ti)N. Mg precipitates have the effect of improving ductility and end-face properties. See the specification at p. 16, ll. 22-36

In order to control the critical amounts of Mg, O and S, the three claimed equations were conceived to allow the precipitation of Mg-sulfides while impeding the precipitation of Mn-sulfides resulting in combined precipitation of MgO, MgS and (Nb,Ti)N, thus improving ductility and end-face properties.

The amount of Mg relative to the amount of O must be controlled to produce Mg sulfides sufficient to improve hole expandability while retaining tensile strength. The inventors discovered that Mg must be greater than 80% of the assayed amount of oxygen and

that the amount of Mg should be controlled according to equation (1): $[Mg\%] \geq ([O\%]/16 \times 0.8) \times 24$. As a person of ordinary skill in the art would understand, in equation (1), 16 represents atomic mass of O and 24 represents atomic mass of Mg. The right side of equation (I) represents the amount of Mg which combines with O.

Sulfur is essential in forming the required Mg-sulfides but also forms Mn-sulfides when present in large quantities causing deterioration of hole expandability. Based on this understanding, the inventors discovered that controlling the upper limit of S content with respect to Mg and O according to equation (2) allows to inhibit MnS precipitation: $[S\%] \leq ([Mg\%]/24 - [O\%]/16 \times 0.8 + 0.00012) \times 32$. As a person of ordinary skill in the art would understand, in equation (2), the first term on the right side of the equation corresponds to the stoichiometric amount of Mg, the second right side corresponds to the stoichiometric amount of O which combines with Mg, the third right side represents a correction factor in accordance with securing the inventive properties, and 32 represents S atomic mass.

The proportion of S to Mn is constrained according to equation (3); $[S\%] < 0.0075/[Mn\%]$, based on the solubility product of Mn and S, to ensure inhibition of Mn-sulfide precipitation. If the S content exceeds more than equation (3), a large quantity of Mn-sulfides and hole-expandability deteriorates. The specification describes that large quantities of Mn and S inhibit Mg-sulfides production and prevent sufficient improvement of hole-expandability. See, the specification as filed at page 14, lines 1-5.

As discussed above, controlling the amounts of Mg, O, S, and Mn according to equations (1) to (3) allows sufficient Mg-S precipitation based on the discovery that Mg-sulfides can be used for achieving uniform and fine precipitation of (Nb, Ti)N, which conventionally has not been recognized. The inventors also discovered that not less than 3.0 μm of the combined precipitates of MgO, MgS and (Nb, Ti)N must be present.

The proportion of Al and Si is constrained according to equation (4); $[Si\%] + 2.2 \times [Al\%] \geq 0.35$ (4). The specification describes that Si and Al are very important elements for the structure control to secure ductility. The proportion of Si to Al needs to be limited in order to secure chemical compatibility and prevent surface irregularities, e.g., Si-scale which are detrimental to formation of chemical treatment films and adherence of paints. Also, the total amount of both Si and Al must be limited to avoid excess ferrite and thereby secure the desired strength. Particularly when ductility is important, the combined content

should preferably be not less than 0.9. See, the specification at page 15, line 37 through page 16, line 5.

Furthermore, the present inventors have discovered that limiting the contents of C, Mn, Ti, and Nb in steels primarily containing bainite (claim 1) is effective for securing ductility while maintaining strength and good hole-expandability by improving the end-face properties of punched holes by Mg-precipitates. See, specification at page 16, lines 31-36. The proportion of C and Ti controlled by equation (5) ensures hole expandability and the proportion of C to Mn is controlled by equation (6) balances strength and ductility. In order to secure strength in excess of 980 N/mm^2 it is necessary to control the proportion of C, Mn, Ti and Nb in accordance with equation (7). .

In order to secure the adequate amount of ferrite in the steels primarily containing ferrite/bainite steel (claim 9) effective for the enhancement of ductility, C, Si, Mn and Al contents must satisfy equation (8) given below. If the value of equation (8) is smaller than -100, ductility deteriorates because an adequate amount of ferrite is not obtained and the percentage of the second phase increases. $-100 \leq -300[C\%]+105[Si\%]-95[Mn\%]+233[Al\%]$ (8). See, the specification at page 20, lines 1-8.

As previously discussed, these equations are not general formulae, but constraints on amounts of respective added elements which characterize steels having excellent tensile strength, hole expandability and ductility

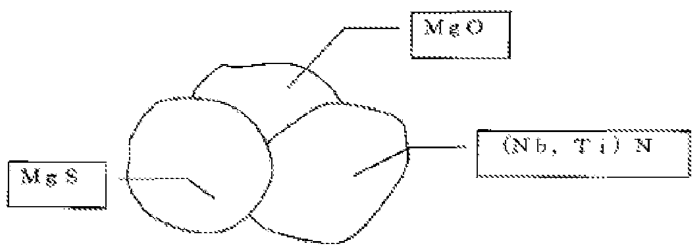
In contrast, JP'543 teaches steel sheets having a structure of primarily ferrite. See, translation of JP'543, p. 36, first paragraph, and pp. 43-45, ¶¶ [0006]-[0010]. JP'543 does not teach or suggest steel sheets having a structure of primarily bainite, nor sufficient tensile strength. JP'543 does not teach or suggest controlling the oxygen level to not more than 0.005 %, controlling the amounts of Mg, O, S, and Mn in accordance to equations (1) to (3), or controlling the amounts of C, Mn, Ti, and Nb in accordance with equations (5)-(7).

JP'543 does not teach or suggest the claimed composite precipitates of MgO, MgS and (Nb, Ti)N. Instead, JP'543 teaches MgO inclusions or combined precipitates, such as Al_2O_3, SiO_2, MnO and Ti_2O_3, or combined precipitates surrounded by (Nb, Ti)N, as shown in the following Fig. 1, which are quite different from those of the present invention. More precisely, JP'543 describes that MgO is preferable with one or more complex oxides such as Al_2O_3, SiO_2, MnO and Ti_2O_3. See, paragraph [0027]. Further, Mg and $MgAl_2O_4$ mainly have

an effect of form of fine void by means of neighboring precipitation of (Nb, Ti)N neighboring those complex oxides, and it is considered MgO and $MgAl_2O_4$ contribute as nuclei for uniform distributed precipitation. See, paragraph [0028]. Fig. 1 shows a comparison of the present inventive combined precipitates and the inclusion described in JP'543.

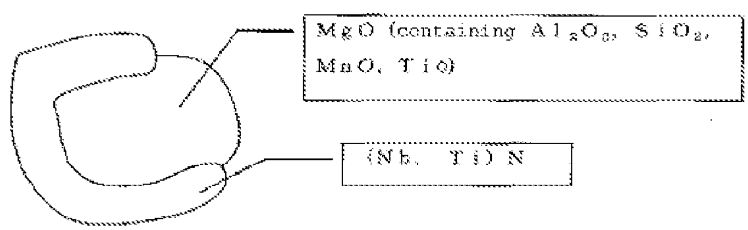
Fig. 1

Present inventive combined precipiates



Inclusion disclosed in D1

Inclusion disclosed in JP'543



Furthermore, JP'543 does not teach or suggest Al in the amount from 0.08% to 1.5%. In contrast, JP'543 teaches conventional Al addition and that an Al in excess of 0.07% should be avoided since it would prevent the formation of essential Mg-Al complex oxides of the JP'543 technology. See, JP'543 at paragraph [0024].

In the Office Action, the Examiner acknowledges that JP'543 does not teach the bainite structure required by claim 1. However, the Examiner suggests that the US'968 generally teaches that microstructure is controllable and that it would be obvious to a person of ordinary skill in the art to adjust the microstructure of the JP'543 steel as demonstrated by US'968 and arrive at the presently claimed bainite (claim 1) or ferrite+bainite (claim 9) microstructure. For support, the Examiner cites to US'968 teachings of a fine bainite structure having high tensile strength (990-1201 MPa) and hole expandability (hole expanding ratio: 155%-170%), i.e., Samples No. 2-4 and 7 in Table 3 and Samples No. 3,6, 7,

and 13 in table 5 of US'968. See, office action at page 5.

However, in contrast to the Examiner's contention, the steels of JP'543 and US'968 are not similar and rely on distinct elements in the composition in order to arrive at the desired properties of their respective steels. For example, the JP'543 steel requires Mg from 0.0005 to 0.01% in order to precipitate Mg oxides and thereby achieve the mostly ferrite structure with excellent hole expansibility. See, JP'543, p. 42, ¶ [0005]. In contrast, the US'968 steel does not include Mg and instead requires B in order to suppress ferrite transformation in the steel resulting in a bainite microstructure. See, US'968 at col. 7, ll. 50-53. Thus, a person of ordinary skill in the art would not have expected that the microstructure of the JP'543 steel can be adjusted to bainite or ferrite+bainite according to the teachings of US'968 without at least altering its steel composition to exclude Mg, which is an element critical to the remarkably improved hole-expandability in the present invention. Therefore, a person of ordinary skill in the art would not have combined JP'543 and US'968 to arrive at the present invention.

Applicants note that JP'543 teaches that the inventive properties are to be secured by steel having a mainly ferrite microstructure and teaches that:

> Further as a means for improving the hole expansibility, in addition to the properties of the punched hole, improving the local ductility of the base material is effective. To improve the local ductility of the base material, making the structure uniform is effective, but in single phase steel, at the strength aimed at by the present invention, the deterioration of the ductility is large and the targeted properties cannot be obtained. For this reason, the structure of the steel is made a composite structure of mainly a ferrite structure… **To prevent a drop in the local ductility of the base material, the structure of the steel is made mainly a ferrite structure and the remainder a bainite structure**.

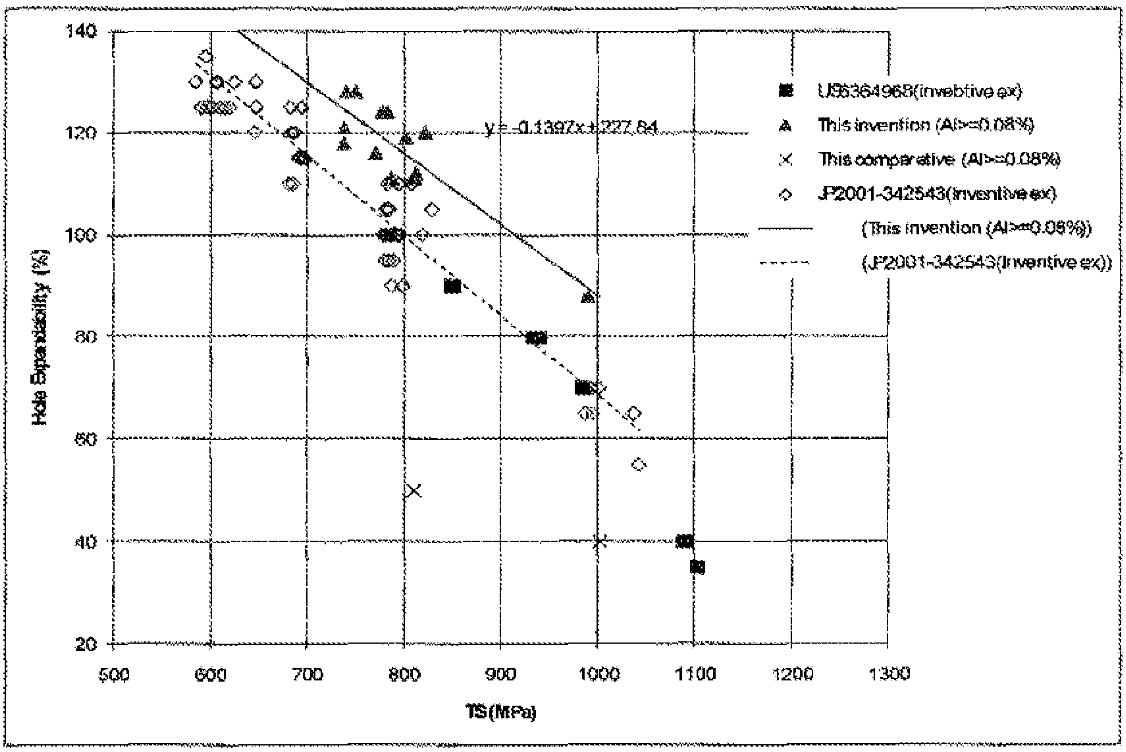
JP'543, at pp. 51-52, ¶ [0032], emphasis added. A person of ordinary skill in the art would not seek to modify the JP'543 microstructure that is attributed with providing the JP'543 steel sheets with its inventive property of excellent hole expandability.

Further, the improved hole-expandability obtained by the present invention cannot be achieved by the conventional technology even if the metallurgical structure becomes bainite. As the conventional discovery regarding hole expandability ratio, Table 5 of the US'968 shows this hole-expandability ratio. This hole-expandability ratio is well known as the

definition that hole-expanding ratio= d/d_0. On the other hand, the present invention defines hole-expandability: $\lambda = (d - d/d_0)/d_0 \times 100$, which is a different value from the conventional hole-expanding ratio.

The figure below shows the relationship between tensile strength TS and hole-expandability ratio among JP'543 (inclusions do not contain Mg-sulfides), US'968 (bainite structure without containing Mg), and the present invention. Regarding US'968, the values of hole expanding ratio is converted to hole-expandability for comparison.

FIGURE 2



The value of the hole-expandability according to the present invention exhibits superior value of hole-expandability than that of JP'543 which does not contain Mg-sulfides and that of US'968 which has a bainite structure without containing Mg. This supports that it is in fact difficult to achieve the advantages of the present invention in view of the conventional technology. Therefore, the present invention provides improved hole-expandability by means of precipitation of Mg-sulfides and the resultant steel sheet has superior hole-expandability, which has not been achieved.

The Examiner also acknowledges that JP'543 does not teach or suggest Al in the amount from 0.08% to 1.5% as recited by claims 1 and 9. However, it is the Examiner's opinion that US'529 discloses a steel in which all of the *major composition ranges* overlap that of JP'543 and the instant invention. The Examiner cites to US'529 Fig. 2 and Col. 7, lines 60-67 for disclosing Al in an amount of not more than 0.1-2.0%, and for teaching that Al improves ductility and hole expandability of the alloy. See, office action at page 6.

However, contrary to the Examiner's contention, US'529 teaches a steel having a distinct composition as compared to that of JP'543. In particular, JP'543 teaches that Mg is one of the most important elements used in the invention. Mg forms oxides which suppress crack formation (JP'543 at ¶ [0023]). JP'543 further teaches that Al is a critical component for interacting with Mg to suppress crack formation. However, the amount of Al cannot be more than 0.07%. Otherwise, the critical effects of Mg will be impaired. Specifically, JP'543 discloses:

> Al is one of the most important additive elements in the present invention. Al easily forms $MgAl_2O_4$ composite oxides having a spinel structure when Mg is added. $MgAl_2O_4$ composite oxides are a form of the finest oxides among composite oxides of Al_2O_3, SiO_2, MnO, and including MgO and are believed to be effective for making the state of dispersion of the oxides more uniform and finer. For this reason, at the time of punching, fine voids are formed. These suppress the stress concentration and thereby are believed t o have the effect of suppressing the formation of coarse cracks and are believed to have the effect of improvement of the hole expansibility. Due to this, 0.002% or more is added. However, *if the amount of addition increases, the effect of addition of Mg is impaired, so the amount is made 0.07% or less*. In particular, to raise the ratio of the MgAl composite oxides among the composite oxides in the oxides and efficiently achieve greater fineness of oxides, the amount of addition is preferably 0.02% to 0.07%.

JP'543 at ¶ [0024] from the translation provided with the response filed September 8, 2009, emphasis added.

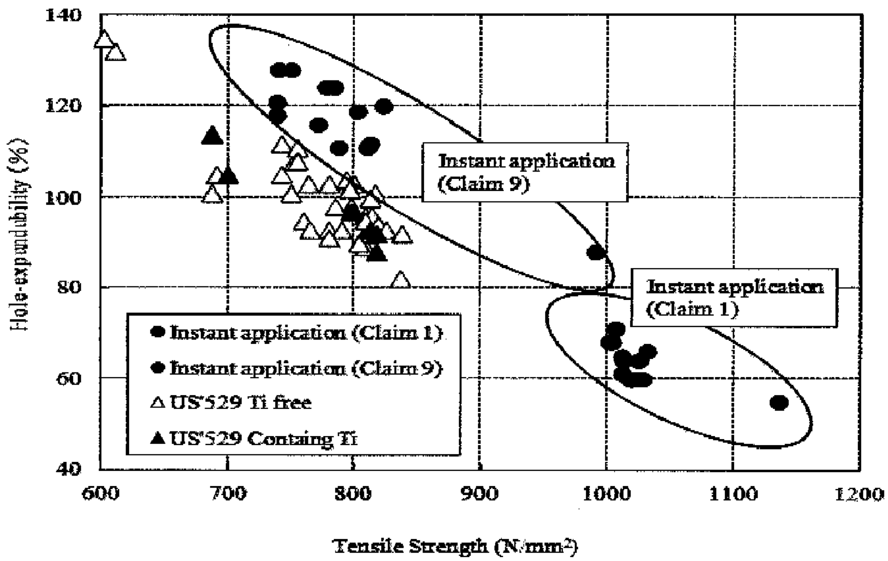
In contrast, US'529 does not teach or suggest a steel composition having Mg. Nor does US'529 recognize the effects of Al on a Mg containing steel. A person skilled in the art would have recognized that increasing the amount of Al in the JP'543 Mg-containing base steel in accordance with the US'529 teachings would have defeated the JP'543 invention and led to a steel unsuitable for the purpose of JP'543, e.g., suppressing the formation of coarse cracks. Thus, JP'543 teaches away from the Examiner's proposed combination and a person skilled in the art would not have combined JP'543 and US'529 in such a manner.

Further, the steel sheet of US’529 contains Ti in an amount of 0-0.10% for precipitating carbonitrides in the ferrite phase to increase tensile strength. This effect is saturated at Ti of 0.10%. The largest amount exemplified is 0.032%. On the other hand, in the present invention, Ti can be added in an amount of Ti:0.130-0.2% in case of the steel contains bainite structure, and Ti:0.120-0.2% in case of the steel contains ferrite and bainite composite structure for remarkably increasing hole-expandability property.

This is specifically mentioned in the specification [0098] as "Ti and Nb are among the most important additive elements used in the present invention. Ti and Nb effectively form carbides, increase the strength of steel, contribute to the homogenization of hardness and, thereby, improve hole-expandability. Ti and Nb form fine and uniform nitrides around the nucleus of Mg-oxides and Mg-sulfides. It is considered that the nitrides thus formed inhibit the generation of coarse cracks and, as a result, dramatically enhance hole-expandability by forming fine voids and inhibiting stress concentration."

Further, the improved hole-expandability obtained by the present invention cannot be achieved by the conventional technology even if the steel includes Al as taught by US’529. Fig. 2 below shows a relationship between hole-expandability (%) and tensile strength (N/mm^2) regarding the present invention and Examples shown Tables 3-1, 3-2, 4-1, 4-2 of US’529 using hot rolled steels shown in Table 2-1, such as Steel No.s, 4, 5, 8,13, 14, 16, 17, 19, 21, 23-25, 27, 29, 34-36, 40, 42 and 43. As clearly seen in Fig. 2 below, the Examples of US’529 do not exhibit improved hole-expandability. On the other hand, the steels according to the present invention remarkably improved hole-expandability.

FIGURE 3



Applicants further respectfully submit that, as Figures 2 and 3 above show, none of the cited references achieves the hole-expandability of the presently claimed steels. There is no reason why a person skilled in the art would have expected that combining these references would have led to steels having the hole-expandability of the presently claimed steels.

Also, the Examiner contends that the presently claimed steel sheets can be achieved by routine optimization of the amounts of the added elements. Applicants respectfully submit that "[a] particular parameter must first be recognized as a result-effective variable, *i.e.*, a variable which achieves a recognized result, before the determination of the optimum or workable ranges of said variable might be characterized as routine experimentation." MPEP at p. 2100-152 (rev. 6, Sept. 2007). In the present case, each of the recited equations defines a relation of the amounts of two or more added elements, which must be satisfied to achieve the tensile strength, high hole expandability and ductility as discussed above. For example, equation (1) $[Mg\%] \geq ([O\%]/16 \times 0.8) \times 24$ requires that the amount of Mg be no less than a quantity determined based on the amount of O. In order to find such an equation, a person skilled in the art would have to first discover a correlation between the amounts of Mg and O, e.g., hole expandability and ductility, and then experiment to find the relation between the amounts of Mg and O and to obtain the equation. None of the cited references recognize a correlation between the amounts of Mg and O, nor is there any constraint on their relative amounts. None of the cited references teaches or suggests controlling the amount of O to be

above the claimed threshold. Therefore, the relation as defined in, e.g., equation (1) is not recognized as a result-effective variable. The same applies to each of the rest recited equations. A person skilled in the art would not have arrived at these equations by routine optimization since the basic principle that MgS precipitates improve fine dispersion of (Ti,Nb)N precipitates is not known.

Therefore, claims 1, 9-11, 19 and 20 are not obvious under 35 U.S.C. § 103(a) JP'543 in view of US'968 and in further view of US'529.

Conclusion

It is submitted that in view of the present amendment and foregoing remarks, the application is now in condition for allowance. It is therefore respectfully requested that the application, as amended, be allowed and passed for issue.

Respectfully submitted,

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